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Remarks on the nature of confined polymers

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高分子鎖の閉じ込めには、二つの定性的に異なる形態があることを提案する。それにより、閉じ込められた高分子鎖の静的、及び動的な性質を議論する際の見通しのよい描像を与える。特に、強い閉じ込め (*strong confinement*) という概念の導入により、従来の理論と不整合な実験結果の説明のみならず、新奇な現象の予言も可能となる。

1 Polymers in confined spaces

When a polymer (made of N monomers of size a) is trapped in a space, whose characteristic size D is smaller than the natural polymer size in a bulk, $R = aN^\nu$, the polymer is regarded as “confined”. Confined chains show up in many situations ranging from industrial problems to fundamental processes in biological cells. As a consequence, a lot of efforts have been taken to understand behaviours of confined polymers, which are much different from those in a bulk. In the present report, we introduce the distinction between two qualitatively different confinement modes, which provides us a unified view on the nature of confined polymers

2 Confinement modes

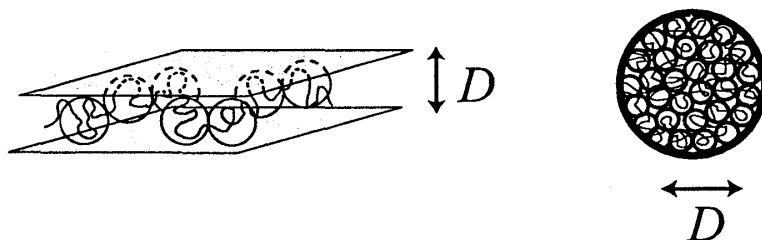


Figure 1: Drawings of the confined polymer. (Left) A linear polymer between plates as an example of the *weak* confinement regime. (Right) A linear polymer inside spherical cavity, which is a simplest realization of the *strong* confinement regime. In both figures, small circles represent “blobs”.

A well-known approach to the confined polymer is based on the scaling argument. It claims that the confinement free energy is proportional to the chain length as a consequence of the

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thermodynamic requirement. This simple statement has been commonly adopted in literatures. However, we claim that this is not always correct, which leads to the notion of *weak* and *strong* confinements (Fig. 1).

In the *weak* confinement regime, the effect of the confinement is purely entropic, i.e., the confinement just reduces the available number of chain conformations, and the conventional scaling argument works out.

However, although not well recognized, polymers could be more and more compressed in some situations. Here, the main contribution to the confinement free energy is energetic (segmental repulsions), as a result of which, the confinement free energy shows unusual nonlinear dependence on the chain length. We define this confinement mode as *strong* confinement. From the local points of view, the strongly confined polymer resembles semidilute polymer solutions. This analogy allows us to obtain various static and dynamical properties of strongly confined polymers, which is expected to play important roles in both material and biological sciences. Which mode of the confinement is realized is in view of the balance between the connectivity of the polymer, in other words, the nature of branching characterized by so-called “spectral dimension” and the space dimension of the confining geometries. Detailed discussions and comparisons with experiments as well as some future suggestions are available in references[1, 2].

Acknowledgment

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References

- [1] T. Sakaue and E. Raphaël, submitted to Macromolecules (cond-mat/0506803).
- [2] T. Sakaue, E. Raphaël, P.-G. de Gennes, F. Brochard-Wyart, to appear in Eur. Phys. Lett. (cond-mat/0504586).